Joint Inversion for Mapping Subsurface Hydrological Parameters

Ki Ha Lee and Hung-Wen Tseng
Contact: Ki Ha Lee, 510/486-7468, khlee@lbl.gov

RESEARCH OBJECTIVES

One of the main objectives of geophysical inversion is to describe various subsurface processes involving fluid flow. Hydrological properties such as fluid electrical conductivity and rock porosity cannot be directly obtained with conventional inversion techniques. The electromagnetic (EM) field propagating in the subsurface is a function of bulk conductivity, which in turn may be empirically related to porosity, pore-fluid conductivity, saturation, and occasionally the temperature. Similarly, the amplitude, phase, and velocity of seismic waves depend on several factors (such as porosity, density, elastic constants, temperature, and pressure). The objective of this study was to develop methodologies for directly mapping hydrological parameters using joint analysis of different geophysical data, along with the empirical relationships between geophysical and hydrological parameters.

APPROACH

To assess the feasibility of deriving hydrological properties directly, we introduced a joint-inversion technique using electromagnetic (EM) and seismic travel-time data (Tseng and Lee, 2001). Because of the limited capability inherent to the inversion techniques used, we decided to investigate advanced inversion schemes for the improved joint inversion. Most of the EM inversion studies in the literature involve full waveform, but there is a lack of similar studies in the seismic area. Full-waveform inversion of seismic data is difficult, partly because of the lack of precise knowledge about the source. Since currently available approaches involve some form of source approximation, inversion results are subject to the quality and choice of the source information used.

ACCOMPLISHMENTS

A new full-waveform inversion scheme has been developed in this research program, exploiting the useful property of the normalized wavefield. A gather of seismic traces was first Fourier-transformed into the frequency domain, and a normalized wavefield was obtained for each trace in the frequency domain. Normalization was done with respect to the frequency response of a reference trace selected from the gather. The source spectrum was eliminated during the normalization procedure. With its source spectrum eliminated, the normalized wavefield allowed us to construct an inversion algorithm without the source information. The inversion algorithm minimized misfits between the measured normalized wavefield and the numerically computed normalized wavefield.

The validity of the scheme has been successfully demonstrated using a simple 2-D synthetic model (Lee and Kim, 2003).

SIGNIFICANCE OF FINDINGS

Normalized wavefields depend, for a given source, only on the subsurface model and the position of the source, and are independent of the source spectrum by construction. The significance of this is that full-waveform inversion of seismic data can be achieved without the source information. With the new method, potential inversion errors caused by source estimation (required by conventional full-waveform inversion methods) can be eliminated.

RELATED PUBLICATIONS

Lee, K.H., and H.J. Kim, Source-independent full waveform inversion of seismic data. Geophysics (in press), published electronically on May 20, 2003; Berkeley Lab Report LBNL-49934.

Tseng, H.-W., and K.H. Lee, Joint inversion for mapping subsurface hydrological parameters. Expanded Abstracts, SEG International Exposition and 70th Annual Meeting, San Antonio, Texas, pp. 1341–1344, September 9–14, 2001.

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